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TPAWS RADAR – The Next "STEP"

"SYSTEM TECHNOLOGY EVALUATION PROGRAM"

Presented by
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AeroTech Research (USA), Inc.
June 3, 2004

Outline

- TPAWS Turbulence RADAR – Where are we?
  - NASA B757 FY-02 FLIGHT TEST SYSTEM CONFIGURATION
  - STATE OF TECHNOLOGY READINESS/FEASIBILITY BASED ON FLIGHT TEST RESULTS
- The Next "STEP"- <u>In Service Evaluation</u> Via The Delta Connection
- Summary Remarks

TPAWS End-to-End System Concept

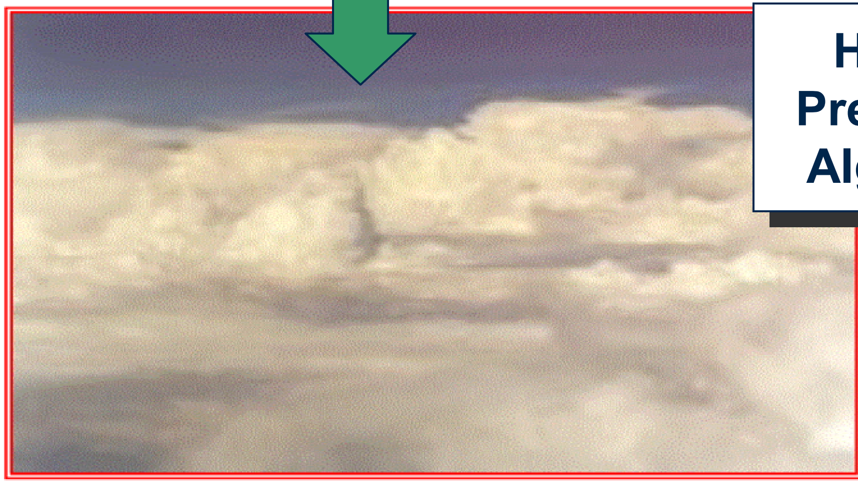
WxR-700 Radar Transceiver & DSP

Turbulence Detection Algorithm

Hazard Prediction Algorithm

Defined Hazard Criteria

Display/ Alert



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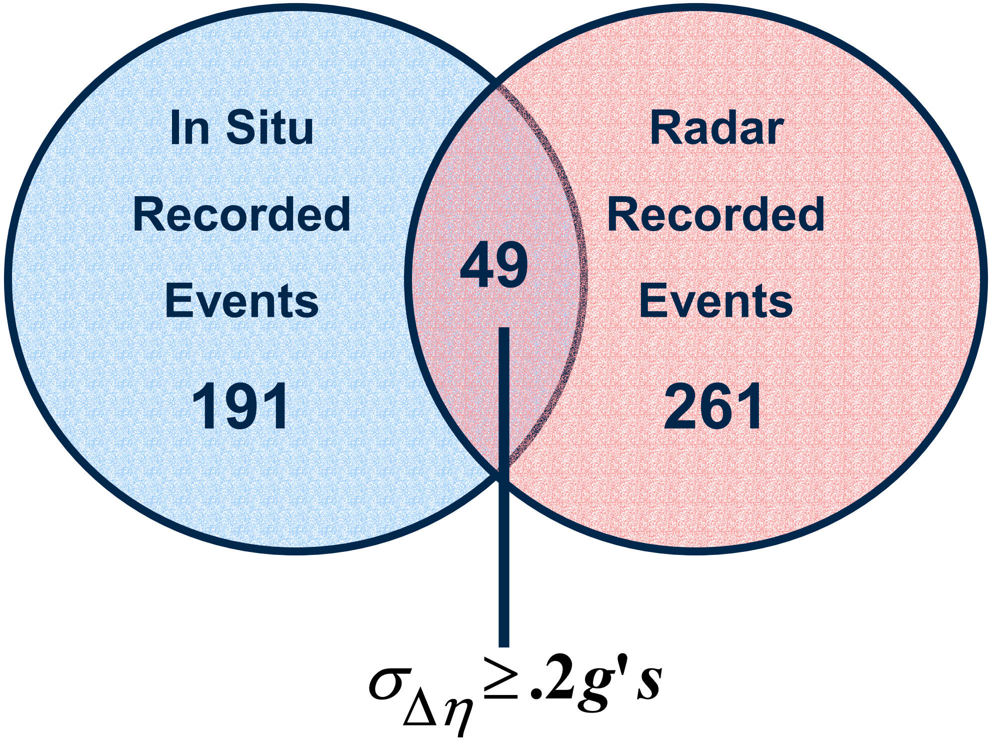
FY-02 Flight Campaign Summary

FY-02 B757 TPAWS Flight Experiment Data Summary



15 flights total: 10 flights encountering significant events

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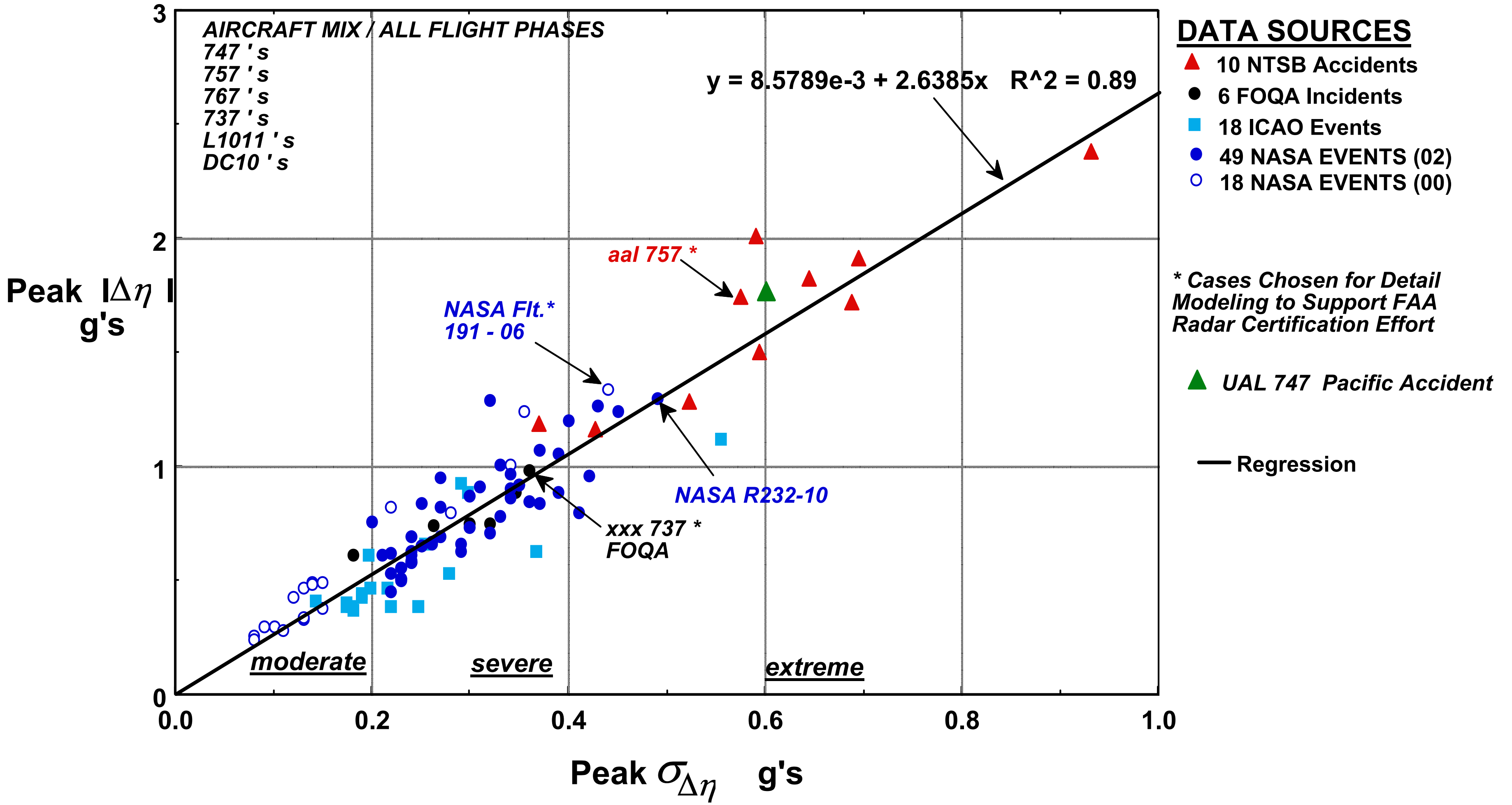
Correlation of Peak Load with Peak RMS Load [5 sec. Window]

Based on Measurements for 102 Turbulence Encounter Cases



ESTIMATED FROM RADAR OBSERVABLES FOR TPAWS CONCEPT

RLB
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R232-10 is a "Show-Case" Event

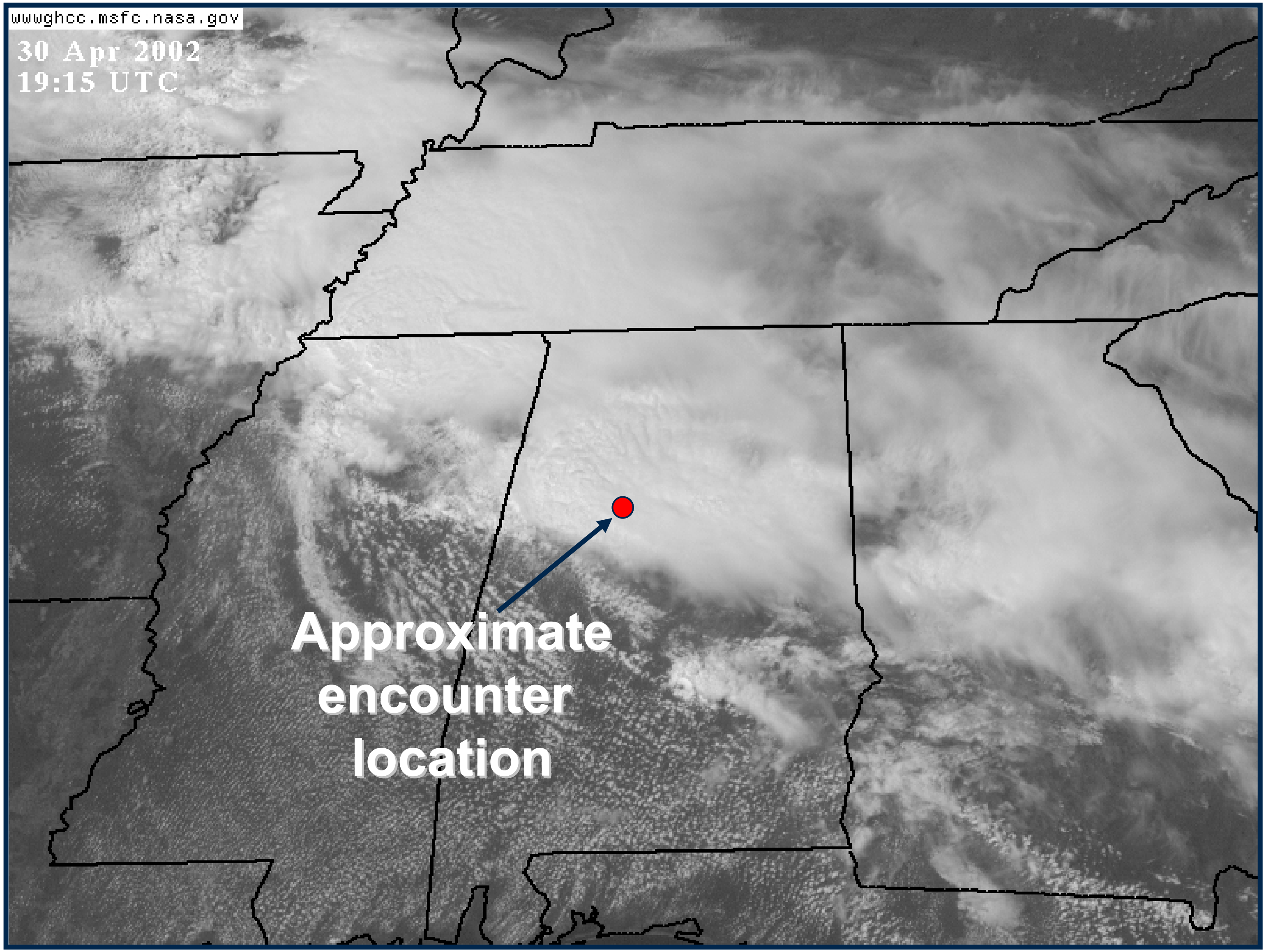
PREVAILING OPERATIONAL SITUATION

- IMC - see and avoid convection not a reliable option.
- Low reflectivity convection in area with localized embedded severe turbulence.
- Conventional "ships" radar-display painting black & green.
- Turbulence PIREPS reported by commercial traffic in the contiguous area.
- Low - reflectivity environment precluded identification of "escape path" prior to encounter.

QUESTION: **Where is the turbulence relative to flight path, and is it hazardous?**

ANSWER: **TPAWS TECHNOLOGY! Exactly the tactical scenario for which the TPAWS design is expected to provide operational safety benefits.**

Visible Satellite Imagery



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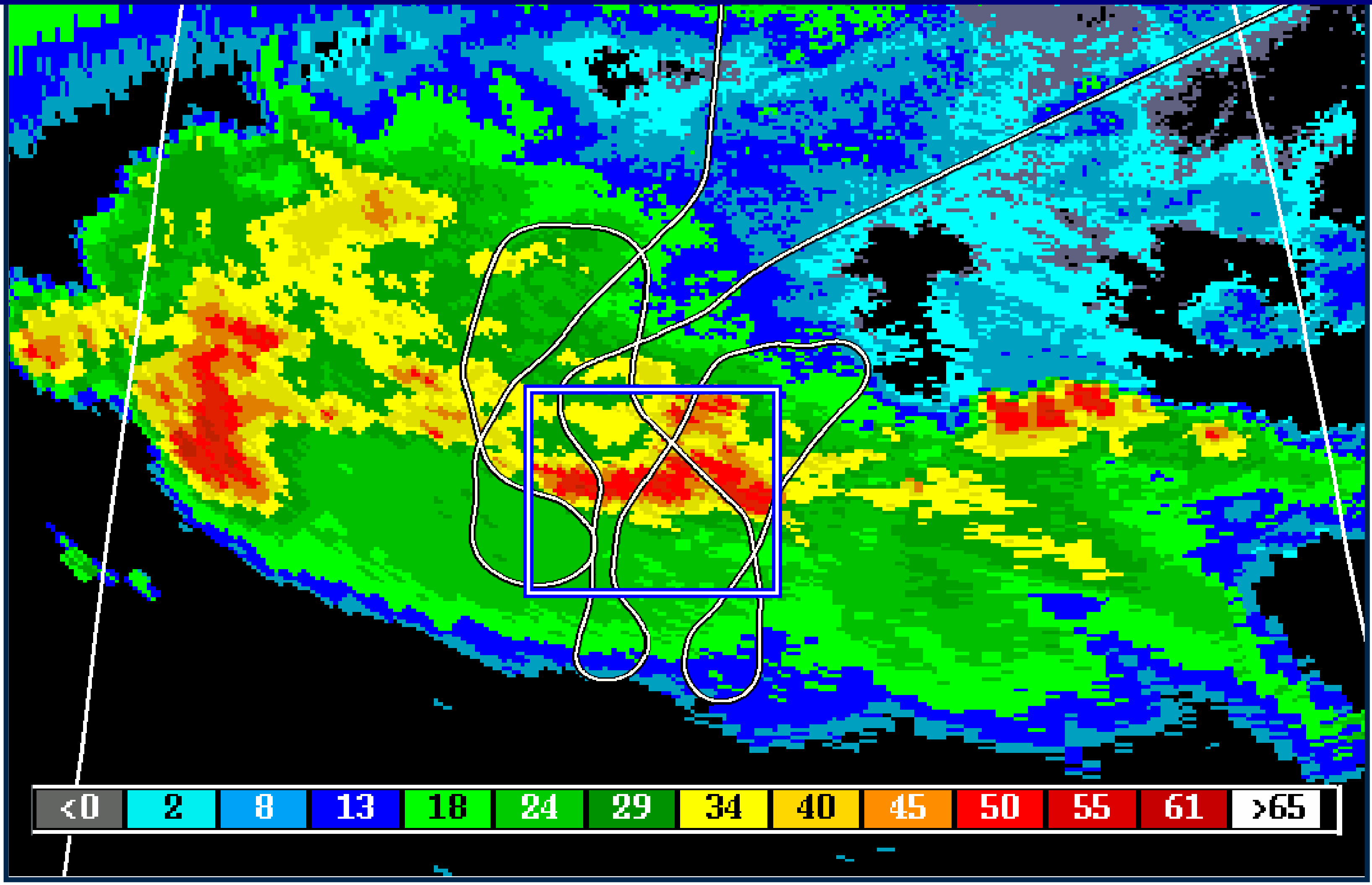
19:12 UTC Huntsville Composite Radar Reflectivity with R232 Flight Path



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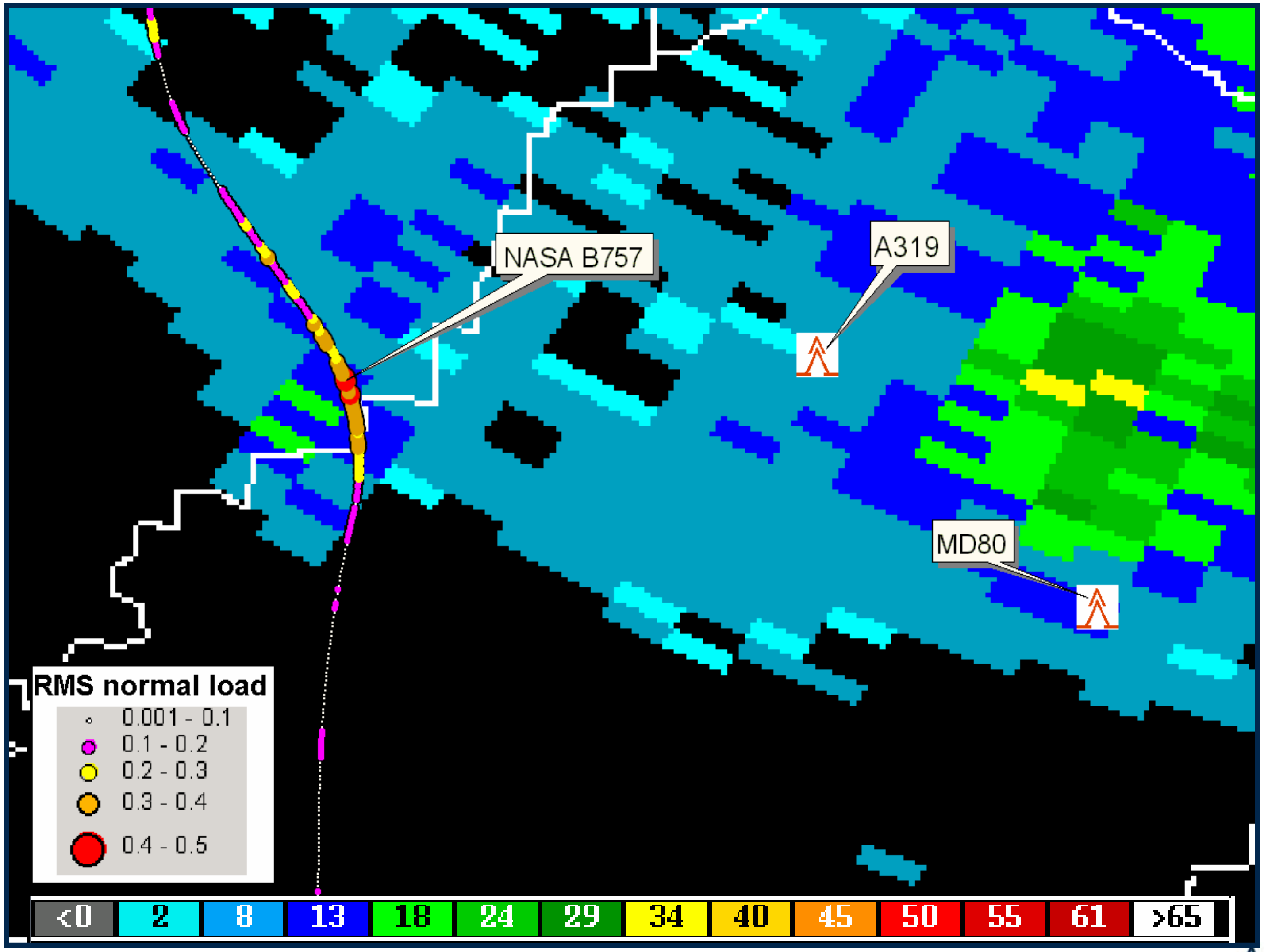
Flight Level Radar Scan From Huntsville Nexrad With Flight Path & PIREPS



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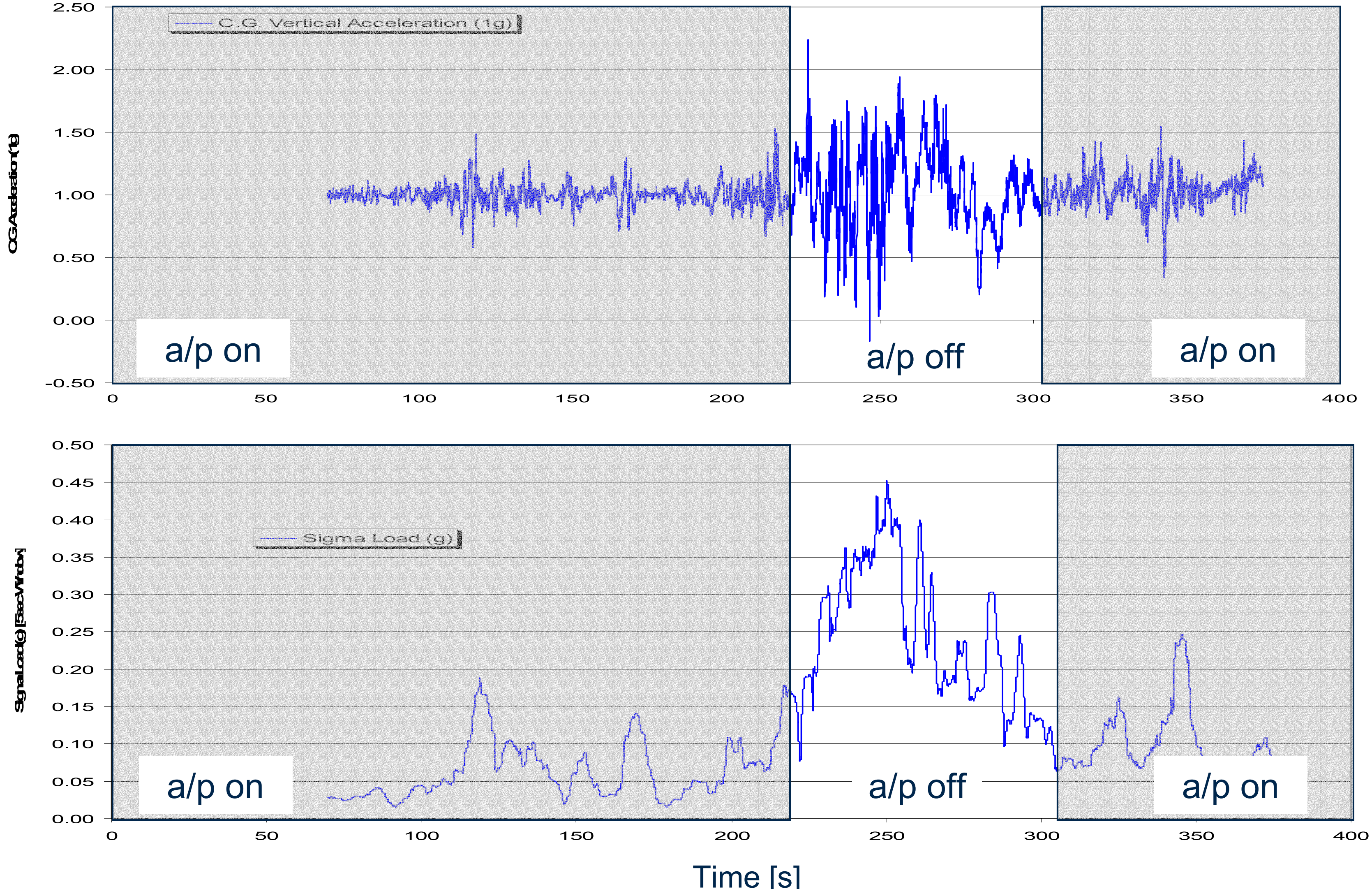
Aircraft C.G. Loads



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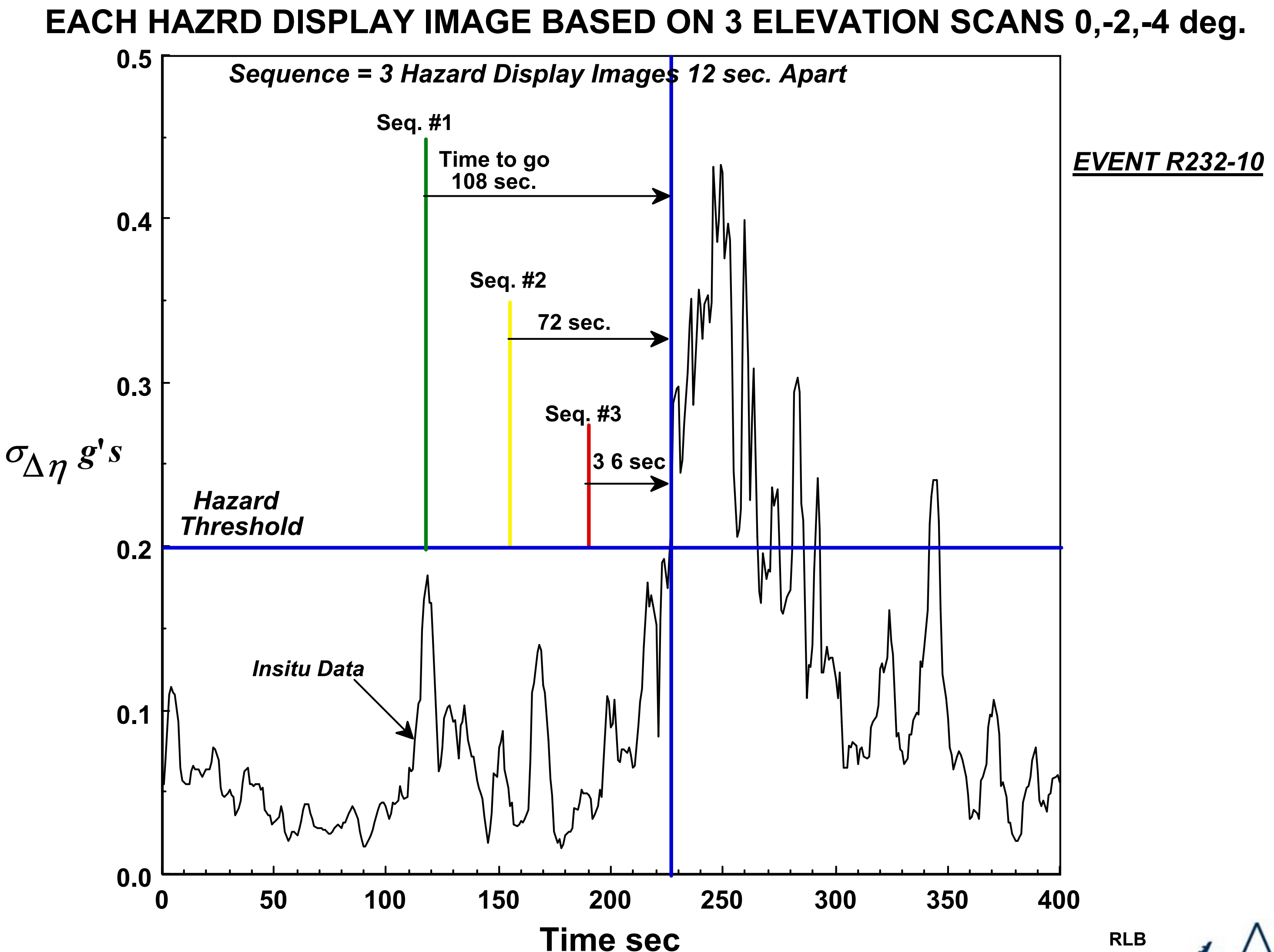
Time Based Radar Position Prior to In Situ Hazard Threshold Exceedence



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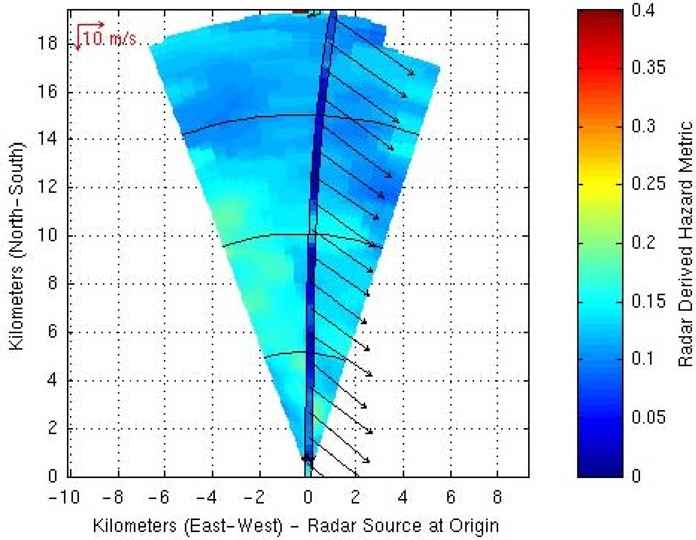
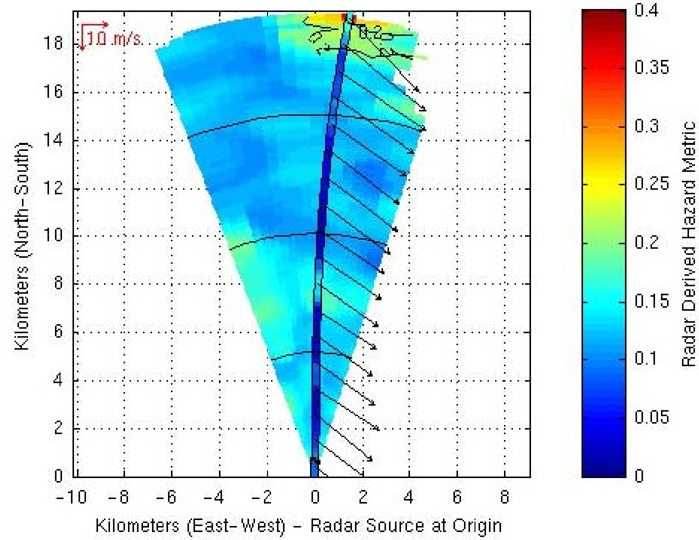
Sequence #1 Hazard Plots

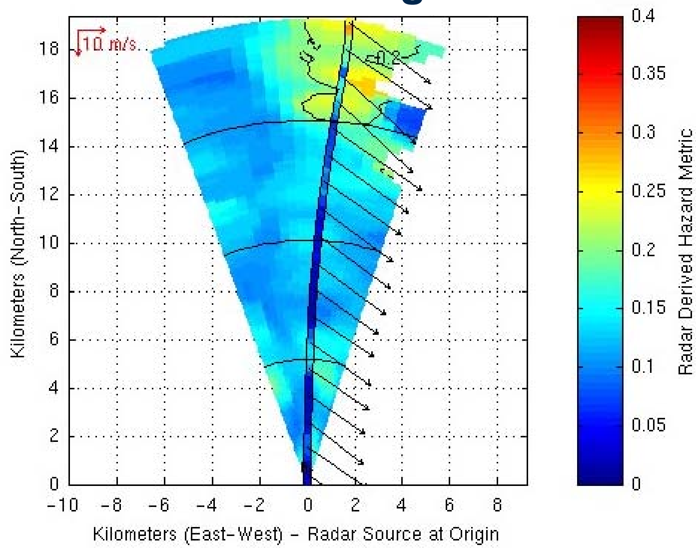
108 sec. to go



96 sec. to go



84 sec. to go



- Range limited to 19.2km (10.4 nmi) by radar experimental configuration (128 range gates)

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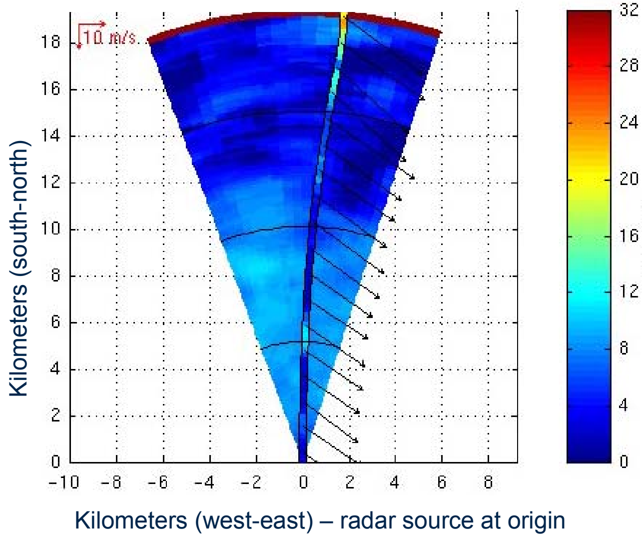
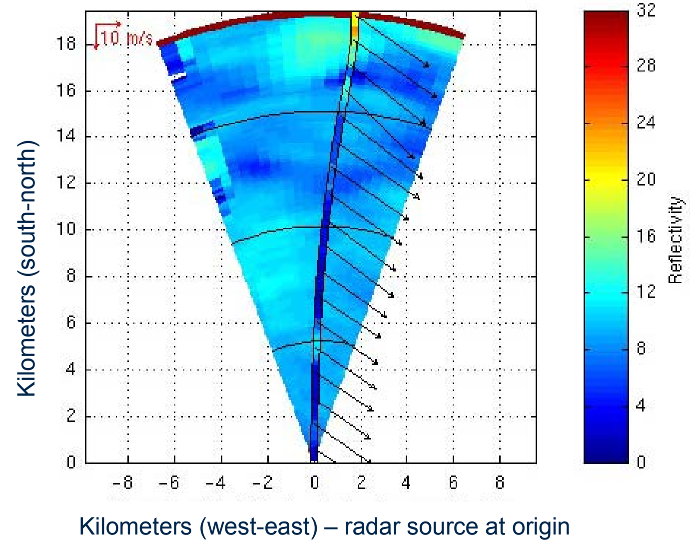
Sequence #1 Reflectivity Plots

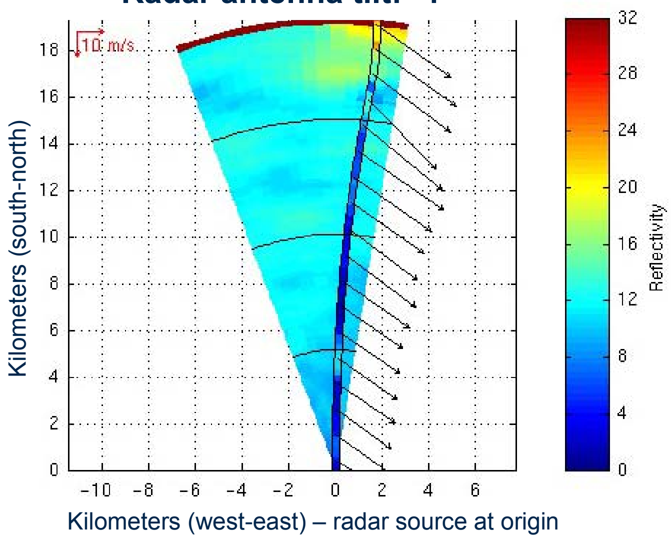
Radar antenna tilt: 0°



Radar antenna tilt: -2°



Radar antenna tilt: -4°



- 84 seconds to go

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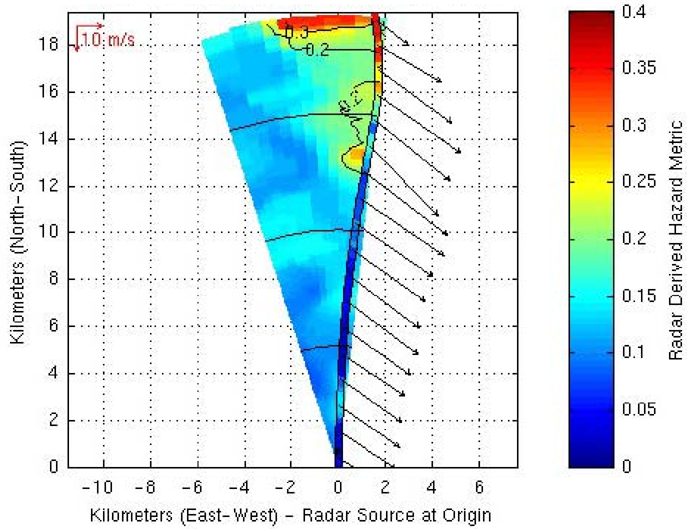
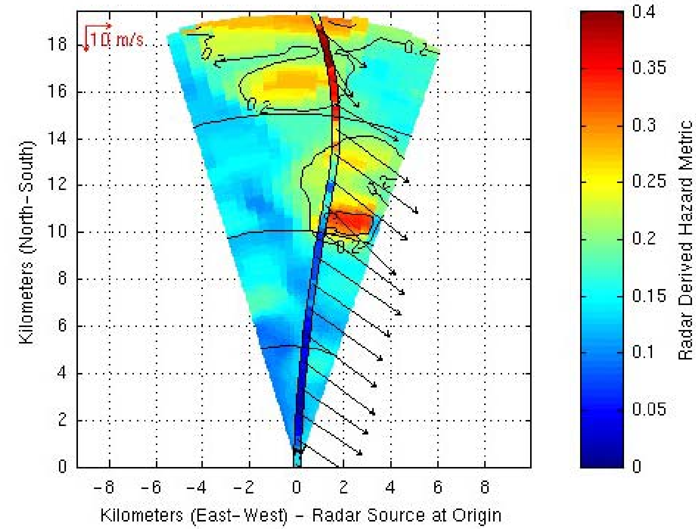
Sequence #2 Hazard Plots

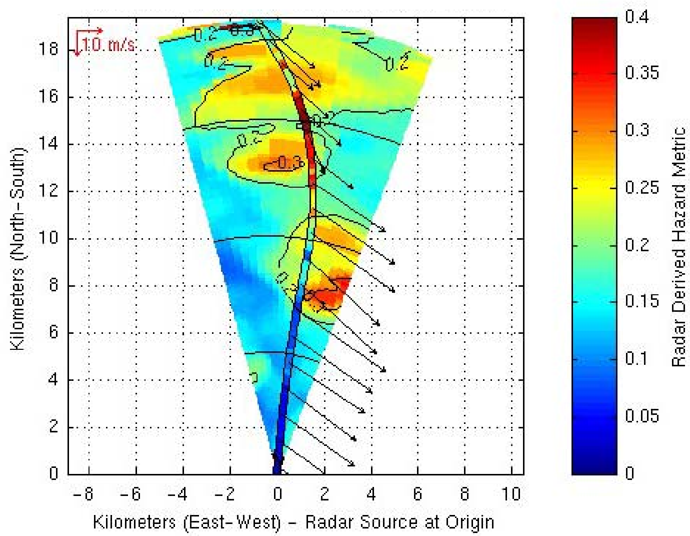
72 sec. to go



60 sec. to go



48 sec. to go



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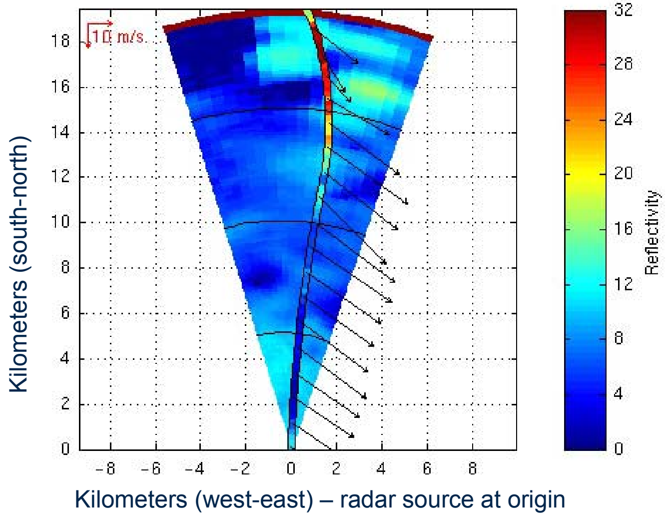
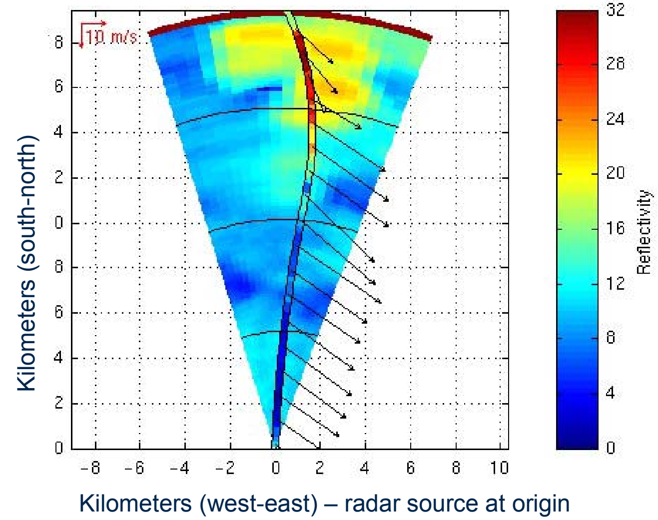
Sequence #2 Reflectivity Plots

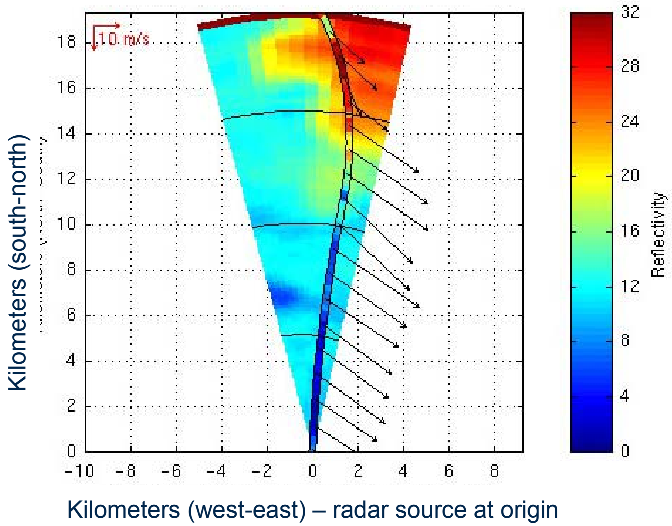
Radar antenna tilt: 0°



Radar antenna tilt: -2°



Radar antenna tilt: -4°



- 60 seconds to go

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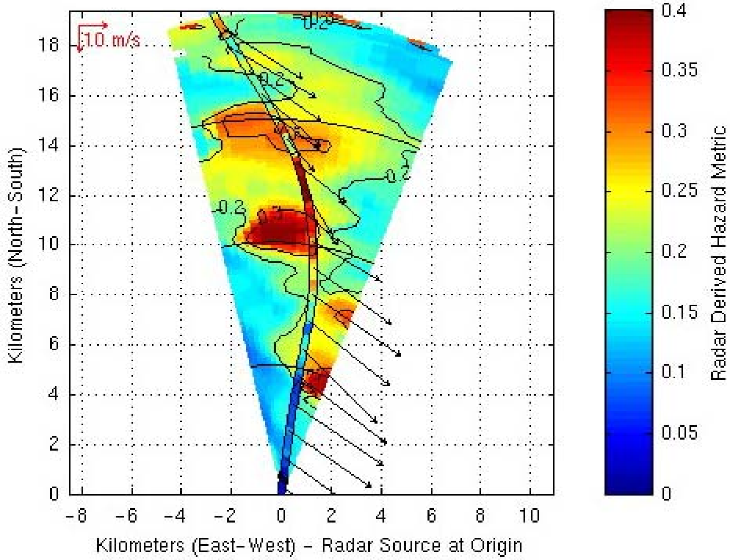
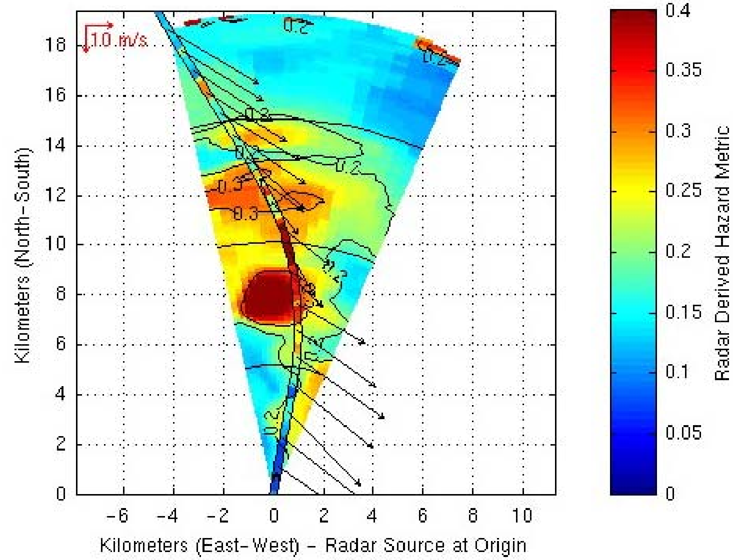
Sequence #3 Hazard Plots

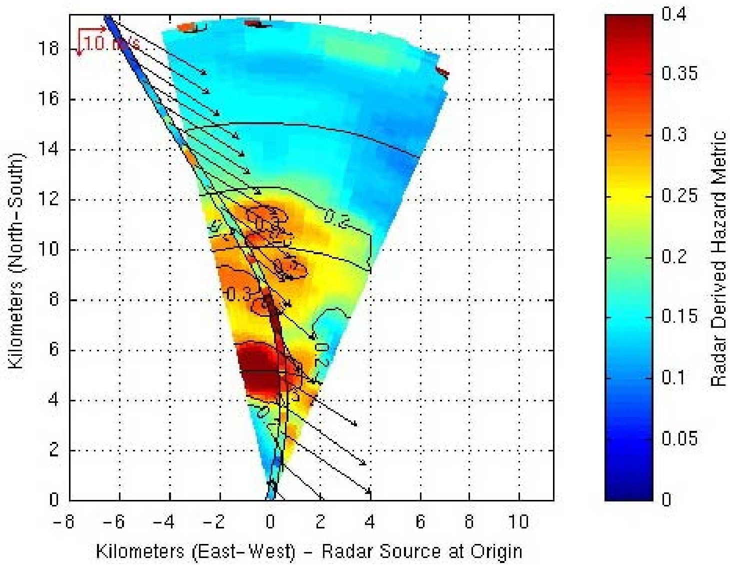
36 sec. to go



24 sec. to go



12 sec. to go



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TPAWS Performance Summary

55 Cases FY-02 Flight Experiment

		Radar ≥ .2 g's	*Radar* < .2 g's
In Situ	≥ .2 g's	**Correct Alerts** $POD =$ 80.95 %	**Missed Alerts** 19.047 %
In Situ	< .2 g's	**Nuisance Alerts** 10.53%	**Correct Nulls** 69.23%

Overall % correct radar detection's = 78.18 %

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Summary Conclusions

- Successful detection of hazardous turbulence convincingly demonstrated.
- NESPA detection performance in low reflectivity conditions considered good.
- Hazard prediction in general agreement with measured In Situ “truth” g-loads.
- Overall system performance exceeds current FAA minimum performance standards.
- Radar system performance for FY-02 flight test demonstrates feasibility of TPAWS technology.

“STEP” Initiative – NASA/ATR Task

In Concert With Delta Air Lines, Rockwell Collins, and Honeywell, Explore Feasibility of Conducting an In-Service TPAWS Radar Operational Demonstration & Systems Technology Evaluation Program

Key Factors Considered

- SYSTEM PERFORMANCE REQUIREMENTS
- COCKPIT INTERFACE / CREW PROCEDURES
- TECHNOLOGY READINESS
- AIRCRAFT PLATFORM SELECTION
- CERTIFICATION (STC’S & TSO’S)
- COST
- SCHEDULE
- ROLES & RESPONSIBILITIES

"STEP" Benefits for NASA

A Clear, Unprecedented, and High Visibility Path for NASA to Successfully Complete Remaining WxAP / TPAWS Milestones and Program Goals

WxAP Goal:
Develop enabling technologies to reduce Wx- related accident causal factors by 25-50% and turbulence - related injuries by 25-50% by year 2007.

Level 2 Milestone:
Evaluation and selected validation of airborne radar turbulence prediction & warning technologies for transport category aircraft in a relevant (Wx & operational) flight environment.

- **Retro-fit**
- **Forward-fit**

"STEP" Requirements

TSO Compliant Certification

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Delta Selected Aircraft “STEP” Platform

B-737-800 NG

Selection Criteria:

- General Availability
- Scheduled Maintenance Down - Time
- Route Structure
- Turbulence Encounter History
- Continental & Maritime Wx
- Avionics Configuration
- Other Factors

Selection of RADAR Manufacturer

Both Honeywell and Rockwell Collins invited by NASA, ATR, and Delta to prepare proposals in support of the "STEP" initiative

Process:

- Face-to-face briefings provided to both companies outlining "step" concept and system technical & operational requirements.
- Companies given two weeks to respond with technical & cost proposals.
- Multi-tiered evaluation procedure defined.

Key Selection Criteria:

- Technical content & understanding of program objectives & challenges.
- Compatibility with delta selected aircraft platform.
- Cost & schedule.
- Other significant factors.

Rockwell Collins selected based on overall technical merit and team judgment as to best aircraft- radar combination

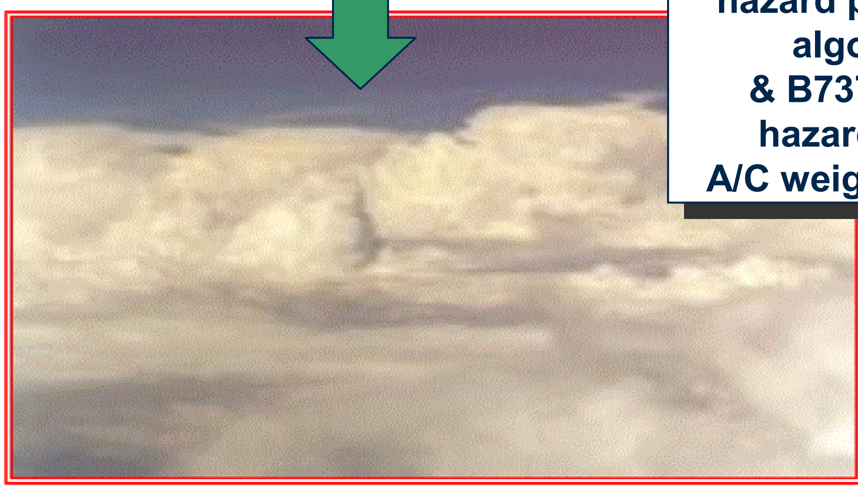
TPAWS RADAR – "STEP" Configuration

" SYSTEM TECHNOLOGY EVALUATION PROGRAM "

ROCKWELL COLLINS Radar System

Installed WXR-2100 multi - scan transceiver & antenna STC's & TSO certified

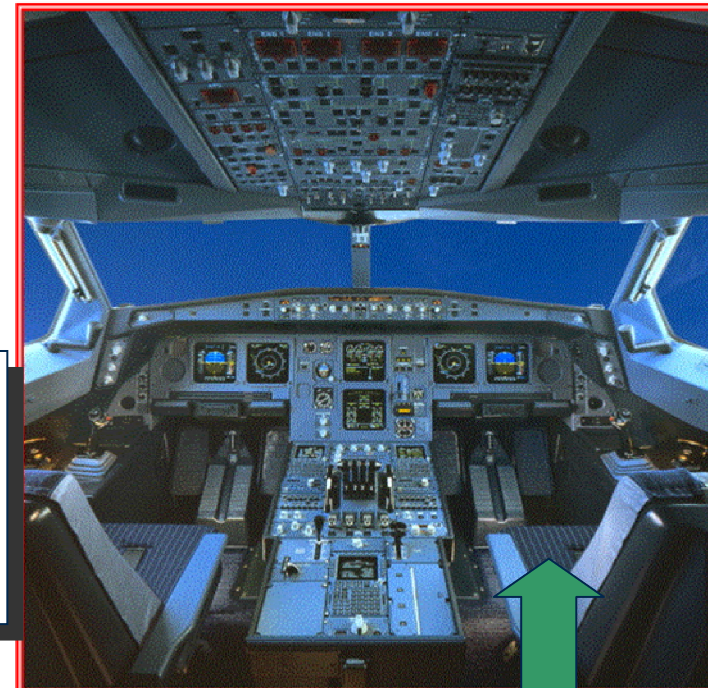
Collins advanced 2nd moment detection algorithm multi - lag auto-correlation



NASA provided hazard prediction algorithm & B737-800 NG hazard tables A/C weight to radar

NASA defined hazard criteria & thresholds

Delta provided B737-800 NG aircraft



Fully Integrated cockpit display 2 level g - threshold "situation" display of advisory information

E - TURB MODE CERTIFIED NON- INTERFERENCE WITH CURRENT WX-MODES / COCKPIT PROCEDURES

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RADAR "STEP" – Key Features

- Insertion of new highly automated WXR-2100 multi scan transceiver technology provides improved performance with STC for B737-800 operation.
- Advanced 2nd moment detection algorithm provides performance equivalent to that successfully demonstrated / evaluated in NASA flight experiments.
- Direct transfer of NASA hazard prediction algorithm technology & related hazard tables tailored for B-737-800 operation. Aircraft weight will be interfaced to radar system to support g- load prediction based on radar observable.
- Long pulse technology will provide detection range performance of 25 - 40 nmi.*
- E-TURB mode provides advisory information via fully integrated two - level situation display based on thresholds of turbulence safety hazard metric, RMS g - load.*
- End - to - end system TSO certified.

* <u>**KEY FINDING:**</u> ***Delta & radar manufacturers require 25-40 nmi. system performance with advisory/ situation display of predicted loads in deference to short range (5-10nmi.) high resolution caution alerts with defined cockpit interference effects.***

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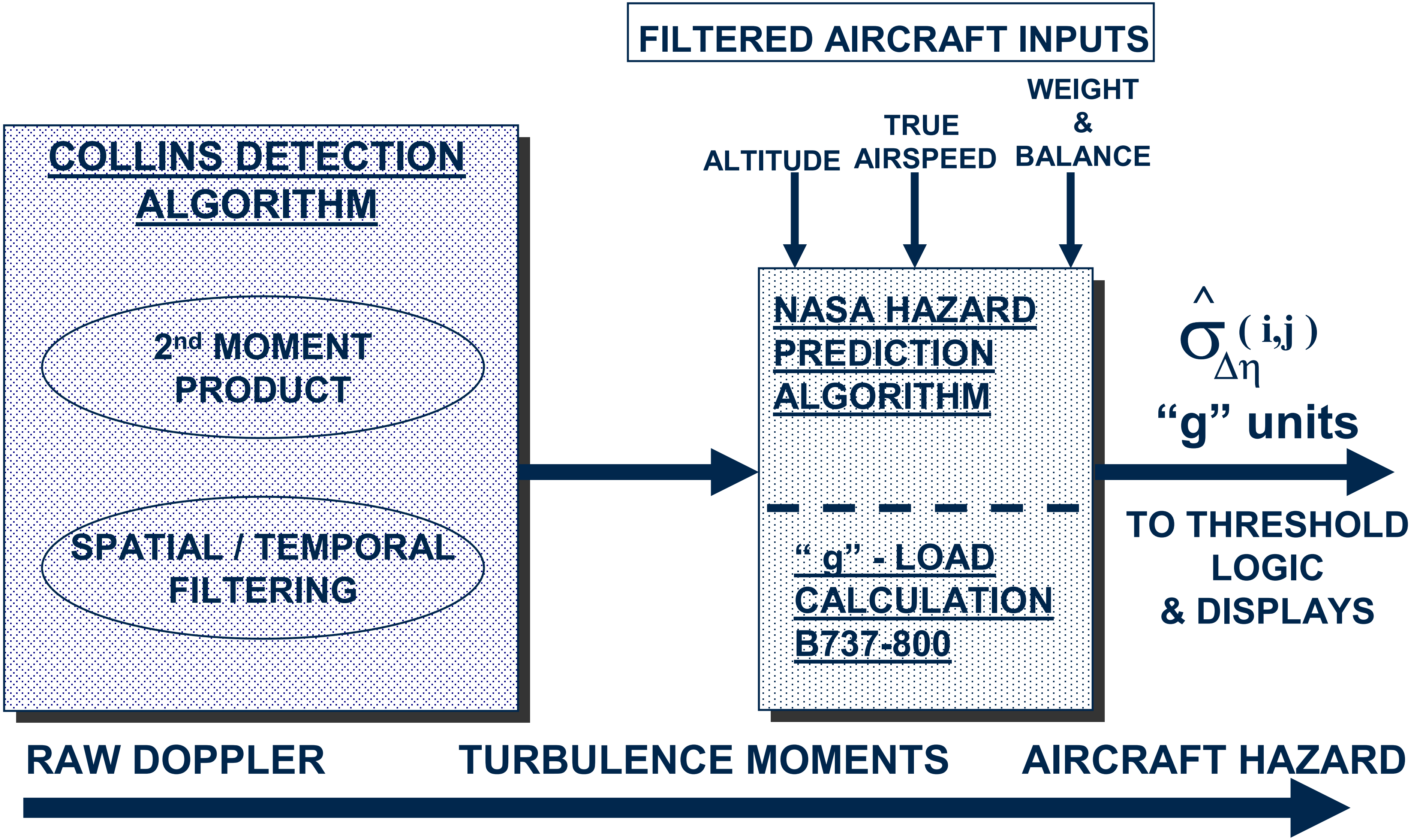
System Implementation Concept



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Functional Organization Chart
RADAR "STEP" Project

- Programmatic oversight
- Funding source
- Participate in evaluation process

NASA

- Project management & oversight
- Develop & provide hazard tables
- Develop & provide pulse volume compensation table
- Fight data analysis
- Participate in evaluation process

AeroTech

- Provide & install radar system
- Acquire all STC/TSO approvals
- Radar engineering & system development
- Functions as systems integrator
- Participate in evaluation process

Rockwell

- Provide aircraft platform & crews
- Engineering & maintenance support for radar installation
- Support STC/TSO process
- Provide flight data
- Participate in evaluation process

Delta

Target Schedule

Key Milestones/ Accomplishments to Date

- Program Start	Dec. /03
- Preliminary Design Review	Mar. /04
- B737-800 Hazard & Pulse Volume Compensation Tables Delivered *	Mar. /04
- WXR2100 RADAR /STC Approval	Mar. /04
- "Ship-Set" R/T& Antenna Installed **	Late Mar./04
- Rockwell Sabreliner Flight Test	Apr. 04
- Final Design Review	Jun. /04
- TSO Certification Approval	July /04
- Evaluation R/T Installed / B737-800 **	July /04
- In- Service Operational Evaluation	Aug. /04 – Aug. /05
- Final Report Delivered To NASA	Sept. /05

* *ATR - Rockwell Coordination* ** *Rockwell - Delta Coordination*

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Summary Remarks

- "STEP" is the right program, at the right time, conducted with the right partners.
- Well thought out plan.
- NASA funding leveraged by substantial in-kind cost sharing by industry partners.
- Program enjoys high visibility with potential for real safety benefits.
- Unprecedented degree of NASA technology transfer.